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Key words
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Secondary bone cancer
Patient-reported outcomes
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Abstract

Regardless of prognosis, surgery is often considered in metastatic bone disease (MBD) as a palliative procedure to improve function and quality of life. Traditional focus on objective outcomes such as mortality is inappropriate in this group, and there is a drive to assess outcomes via patient-reported outcome measures (PROMs). This is an overview of current understanding of MBD outcomes and how this should influence future decision-making and direct research.
The objectives of this review were to identify difficulties in measuring PROMs in the MBD patient population and explore alternatives to patient-reported outcomes. We also provide an overview of current understanding of outcomes in MBD and how this should influence future decision-making and direct research.

Introduction

MBD affects 40-70% of patients with solid organ malignancies, more commonly in breast and prostate cancer(1), and up to 95% of patients with multiple myeloma(2, 3). The presence of widespread bony secondaries in systemic cancer is considered an incurable stage of the disease but surgery is often indicated to restore function, independence and relieve pain(4, 5). However, there is widespread variation in surgical practice(6), and no consistent means of assessing outcomes in this patient group.(4, 7).

Historically, orthopaedic surgery focused on measures such as mortality, complications and revision surgery to assess outcomes after surgery(8, 9). However, as early mortality can be high in this group(10) and patients may not be fit for revision(11), a more recent focus has been PROMs(9).

Using PROMs allows patients to express their outcome in terms of function and quality of life without interpretation by their care provider(12). However, widespread measurement of PROMs in MBD has been slow to materialise for many reasons, including:

- Challenge of defining the goal of treatment in MBD
- Burden of participation for these multi-morbid patients(13)
- Widespread variation and inconsistency in use of PROMs for MBD(5)

The aim of this review was to assess PROMs in terms of quality of life, function and pain relief after surgery for MBD.

What outcomes are important to patients with MBD?

PROMs can measure any parameter of patient outcome after treatment, and usually (but not exclusively) cover outcomes that are difficult to measure objectively, such as quality of life (QOL) and function(2, 14). This is particularly important in MBD since many of the available treatments are given with the intention to relieve symptoms and maximise quality of life (with type of surgery determined through consideration for a patient's prognosis, risk of complications and likely outcome from surgery)(3, 15). In a palliative condition like MBD, quality of life and symptom control are arguably more meaningful and fairer methods of outcome measurement than mortality or revision rate(16, 17).

Skeletal-related events (SREs) secondary to MBD (such as pathological fractures and spinal cord compression) can cause pain, loss of function and a reduced quality of life(18, 19). However, MBD treatments such as radiotherapy and pain-reducing surgery can also lead to negative effects on patient outcome, trading function for pain relief(19). In order to fairly measure patient-reported outcomes after surgery for MBD, we have to consider what outcomes patients prioritise in their care and rehabilitation. This is a difficult task because relevant outcomes from treatment in MBD can vary widely between different individuals. For example, the patient with metastatic breast cancer in their fifties with a young family and a prognosis of years may have very different expectations than the frail patient in their eighties with lung cancer and a prognosis of weeks. However, as a result of improved systemic therapies, more and more people are living longer with bone metastases and our priority for every patient should be to maximise their quality of life for the time remaining to them(20).

Mougalian and colleagues asked patients with metastatic breast cancer about the PROMs that were important to them and identified five domains that were negatively affected by systemic cancer: physical, psychological, function/mobility, social, financial and treatment-related(13) (Table 1). There was significant variation when participants were asked to rank domains by importance, but the most commonly ranked priorities included physical symptoms (such as fatigue and nausea), treatment burden (including visit frequency and invasive procedures) and emotional impact of cancer (including anxiety and depression)(13).

During development of the EORTC BM22, one of the few PROMs validated in MBD, Chow and colleagues noted that feedback from patients was strongly in favour of pain as the primary symptom of importance in MBD(16). Although treatments such as radiotherapy can temporarily reduce other parameters such as mobility and function, the researchers noted that disabilities related to severe pain such as the inability to walk could be improved or even restored through adequate pain relief in many cases(13, 16). In short, each of the key outcomes in MBD are interconnected, and any method for measuring them has to take this into account.

In addition, data collection should not solely focus on the period of inpatient care. In a progressive condition like MBD, function and quality of life can deteriorate after discharge(21) due to disease progression, metalwork failure, infection and other correctable complications of surgery. Many of these patients are deliberately not seen postoperatively, in an attempt to minimise burden of hospital visits and let patients 'get on with their life'. Even when follow-up is planned, there is a high attrition rate due to patient morbidity and mortality(22).

What PROMs do we have for MBD?

MBD-specific PROMs have traditionally been lacking, and this impacts on the interpretation of some of the older studies in the literature(5, 20). With the invention of more recent specific instruments such as the EORTC-QLQ BM22(16) and BOMET-QOL(3), data collection has become more reliable and specific. Table 2 summarises the most commonly utilised PROMs in MBD, and demonstrates which scoring systems are non-specific and which are validated in patients with bone metastases.

Pain

Pain assessment is a key focus of outcome measurement in MBD as both an objective measure (e.g. analgesia use), and as the most frequently reported contributor to poor function and quality of life(23). As summarised in the excellent 2006 paper by Cleeland and colleagues, there is no single pain assessment instrument which can assess all of the facets of pain experienced by cancer patients AND account for the additional trauma of a pathological fracture(24). However, we would recommend the Functional Assessment of Cancer Therapy-Bone Pain (FACT-BP) as it has been validated for use in the metastatic cancer population(25, 26).

Function & mobility

Function is a key outcome in musculoskeletal patients and is defined separately, but with significant overlap, to quality of life. Although both describe an individual's ability to live the life they would choose, we have defined function as the effect of cancer symptoms on a

patient's "physical ability to perform tasks and roles", and quality of life as the more rounded "ability to participate in their chosen lifestyle". Two musculoskeletal oncology scores which have been validated for use in MBD patients are the Musculoskeletal Tumor Society (MSTS) functional assessment form(27) and the Toronto Extremity Salvage Score (TESS)(28). The MSTS score was originally developed as a physician-reported score but has been validated for use as reported by patients (29). Both scores have upper and lower limb-specific variations and although the MSTS has a lower precision than the TESS, it takes significantly less time for participants to complete, a key factor in maximising adherence(30).
Largely comparable to the MSTS and TESS is an adaptive questionnaire, the Patient-Reported Outcomes Measurement System (PROMIS)(30). The PROMIS questionnaire is delivered electronically and adapts according to each answer given, leading to a significantly shorter time for completion(30, 31). Depending on the availability of electronic means of data collection and capture to research teams, this may be a less burdensome option for measuring PROMs in MBD.

Quality of life
Quality of life is commonly taken to cover many of the above terms and comprises the degree to which all of the above interact to allow a patient to live according to their own wishes. The European Organisation for Research and the Treatment of Cancer Quality of Life questionnaire (EORTC-QLQ C-30) is the most commonly used measure of quality of life in studies on patients with cancer(8, 20). In order to address additional bone metastasis-specific issues such as pathological fractures, the EORTC module BM22 was developed in 2009 and is usually administered along with the full EORTC questionnaire(16, 25).

Mood and physical symptoms
No specific tools exist for measuring mood or physical cancer symptoms in MBD. Such aspects of patient outcome are incorporated in larger scores such as the EORTC QLQ-C30 questionnaire or non-specific tools such as the Hospital Anxiety and Depression score (HADS)(32) or Edmonton Symptom Assessment System (ESAS)(33) can be utilised.

What are the difficulties in measuring PROMs in MBD?

In seeking to improve PROM reporting in MBD, there are several key difficulties to address. The PROM should measure the most clinically appropriate endpoint in determining outcome, the burden of participation for such a multi-morbid group should be considered, and the score should reflect the rapidly changing population with systemic cancer.

Does the PROM measure the most clinically appropriate outcome?
Total knee replacements (TKRs) have long been held as an example of the discrepancy between the utility of PROMs in discriminating successful from unsuccessful surgery. Although TKR can be expected to provide excellent pain relief, dissatisfaction rates range from 10-33% and residual functional symptoms range from 33-54%(34-37). This is considered acceptable as long as patients are adequately counselled, and is not a valid argument for refusing to perform TKR on patients with an appropriate level of pain(9). As a result, PROMs used in outcome-measurement should be the most appropriate ones to reflect the reason for surgery (i.e. pain relief) with appropriate pre-operative counselling of patients regarding both

positive and negative effects of surgery(9, 35). This is particularly relevant in the case of patients undergoing surgery for MBD, as this is rarely life-prolonging, but intended to relieve pain and improve function. We have already discussed key outcomes which patients with MBD find important, and these include physical symptoms such as pain and disability, treatment burden and the emotional impact of secondary bone cancer(13).

Burden of participation for patients with MBD

Another difficulty in mass uptake of PROMs for the MBD population is the participation burden. Patients referred to orthopaedics with a bony metastasis in the proximal femur have a mean age of 72 years, a 90-day mortality of 46% and are often under the care of multiple specialities (10). With the added disability of a pathological fracture, this population may have difficulty completing paper forms, attending clinic appointments and who may tire more easily than patients with traumatic fractures.

Prospective studies looking to assess PROMs should minimise participant burden to reduce this risk. Questionnaires should be kept short and relevant, with prioritisation of the key outcome measures based on prior patient-involvement and statistical planning(38). Options to overcome physical barriers such as disability and pain might include recording equipment (to minimise the need for writing) or consultations via email or telephone (to minimise the need to attend physical appointments)(14, 38). Use of proxy data collection by a family member or friend can be used selectively, and there is some evidence that questionnaires such as the EORTC-QLQ C-30 show reasonable consistency between patient- and proxy-reported PROMs (8). Finally, adaptive PROMs such as the PROMIS score(30) are gaining popularity, particularly in frailer patient groups. Adaptive PROMs target questions based on previous answers, and can be significantly quicker, easier and more precise to use(9, 30). There is evidence that these scores can help to include older patients or those with language barriers(8, 39), but they do require the use of electronic devices, which can be expensive or impractical(9).

Do PROM scores reflect changing population?

Thanks to improving systemic therapies for malignancy, patients with MBD are now living longer with a lower disease-burden(40). Although many MBD patients are elderly and frail with prognosis measured in months(10), there is an increasing subgroup of younger, fitter patients with a better prognosis and expectations of surgery beyond simple pain relief. PROMs used in MBD need to accurately reflect patients at both ends of this spectrum(9).

Despite the immediate beneficial effect of surgery for MBD, there is the potential for deterioration over the postoperative course due to progression of the underlying disease. This could mask the beneficial outcomes of surgery and PROMs used should focus on pain relief at the site of surgery or prevention of pathological fracture in those undergoing prophylactic stabilisation (5).

Another vital factor is analysing for the presence of floor/ceiling effects. If the scores used are not sensitive enough, they will fail to differentiate between patients scoring highly at the top of a score (ceiling) or fail to detect subtle problems in those scoring very poorly (floor effect)(41). Many of the PROMs in use have traditionally focused on differentiation between patients scoring poorly in terms of pain, function and quality of life, but the problem of ceiling effect will become more marked as we treat younger, fitter patients with a better prognosis. Studies should focus on outcomes in both specialist tumour- and unselected trauma centres to ensure the whole range of patients with MBD are included in PROM studies. In addition,

patients should be followed up for a clinically relevant timeframe (Ernest Codman's 'end result' principle, whereby patients must be followed up for long enough to measure the appropriate clinical outcomes) and change in trend over time prioritised over cross-sectional outcome studies(9, 42).

Alternatives to PROMs

Subjective outcome measurement is important in MBD to reflect the efficacy of healthcare interventions (in terms of improvement in pain, mobility and quality of life) when surgery is rarely a life-prolonging undertaking. However, there are alternatives to PROMs, as summarised in Table 3. These include performance-based outcome measures, physician-reported outcome measures and quality indicators of outcome. However, the majority of these do not incorporate the outcomes that are considered by patients to be important to them, and none are able to capture patient perspective on MBD surgery.

What do PROMs show in MBD?

Cheng's 2003 review provides a descriptive baseline on PROMs in MBD up until 2001(5). Cheng remarked that most studies were retrospective or cross-sectional, with inconsistent use of PROMs that were not specific to bone metastases (5). They did find early evidence that most patients appear to benefit from surgery, but found it difficult to quantify this improvement due to the variation in PROMs utilised. This section will summarise what is known about PROMs in MBD patients to date.

Pain

Pain is the commonest symptom associated with MBD and is reported by 50-90% of patients(16, 43). Pain is caused by involvement of weight-bearing cortical bone and exacerbation can predict impending pathological fractures(44). Pain severity is higher in patients with multiple metastases but tends to be less severe in some primaries such as lymphoma and prostate cancer(45).

Analgesic use as an objective measure of pain is frequently used but often poorly quantified(23). Talbot and colleagues found a significant reduction in post-operative pain scores at 6 and 12 weeks post-surgery for MBD, but failed to show a statistically significant difference in the pre- and 3-month post-op analgesic use of 84% and 67%, respectively(22). This may reflect the relatively small sample size of the cohort (67 patients) or the effect of outliers.

The cross-sectional nature of most of the available studies neglects to explore concerns about deterioration after surgery due to disease progression. A small study that explored this in terms of pain relief (n=13) showed an improvement in pain scores after internal fixation or arthroplasty for MBD(31). This plateaued between post-operative weeks 12-20 then fell at 6 months, the last follow-up point(31). A much larger study published the same year (n=184) demonstrated a sustained improvement in pain scores at one year post-surgery measured through the non-specific BPI tool(46). Therefore, although evidence in the literature is currently lacking to demonstrate a specific and sustained improvement in localised pain after surgery for MBD, it seems reasonable to conclude that there is no evidence to suggest pain relief is only short-lived after surgery for MBD.

Finally, there is some evidence that the type of surgical procedure influences post-operative pain in MBD. Although no studies have demonstrated a clear difference between methods of internal fixation, arthroplasty or endoprosthetic reconstruction (EPR), a 2010 study of 87 patients comparing IMN and EPR demonstrated similar levels of post-operative pain relief (measured through the MSTS bone tumour-specific PROM) at a median follow-up of 8 months(47).

Function/mobility

Poorer outcome in terms of function is associated with a number of patient variables in MBD, including increasing age, pain severity, medical comorbidities and female gender (in one study)(43, 45, 48). There is some evidence for better function in those with prostate/thyroid primaries and in those who survive more than 12 months after surgery(45, 49). Perhaps surprisingly, there is no significant difference in function for those who did or did not sustain a pathological fracture (mean MSTS 66% for those with fractures versus 67% for those without)(50).

Weightbearing status is infrequently recorded, but reported as 72% of EPR patients during the immediate post-operative period(51). The only study to record medium-term weightbearing status was Furtado's 2015 study on amputation for lower extremity bone tumours (not specific to metastases) which reported a 70% dependence on walking aids at 12 months(43).

Most studies show a continued improvement up to one year in function/mobility as assessed by the MSTS and TESS scores(22, 46, 47, 52). Where quantified, MSTS outcomes range from 15-47% (preoperative values) to 73-90% (8-12 months post-op) (22, 46, 47, 52) and TESS values ranged from 40-44% (preoperative) to 63-75% (3-12 months post-op)(22, 52). Park et al.'s 2007 paper studied patients at a single point from surgery and found high function rates

measured through MSTS (mean 73%, range 57-90%) and TESS (mean 71%, range 46-95%) at an average of 48 months post-surgery(53).
There is conflicting evidence in the literature for any difference in function between the less invasive internal fixation surgical options (e.g. intramedullary nail IMN) compared to excision and EPR. Two studies investigating functional outcome in humeral metastases showed conflicting results, with Bickels and colleagues demonstrating better outcomes in diaphyseal metastases fixed with cemented IMN (mean MSTS 85-100%, n=31) compared to EPR of peri-articular metastases (mean MSTS 70-97%, n=17) at a median follow-up of 1.7 years(54). In contrast, Piccioli's 2010 study showed a difference in mean MSTS of 73% and 79% in favour of EPR at a median 8 months follow-up(47). In a large study comparing methods of lower limb reconstruction for proximal femoral metastases (n=158), Harvey and colleagues demonstrated a difference in mean MSTS of 70% for IMN and 80% for EPR at a mean follow-up of 16 months, but this did not reach statistical significance(55).
We would conclude that although there is conflicting evidence, post-operative function appears to be relatively well restored in all surgical options. The choice for type of reconstruction should be taken based on patient comorbidities, cancer prognosis and with an understanding of the additional risks of EPR.

Quality of life
Quality of life (QOL) in MBD has been largely under-researched in favour of other PROMs such as function and pain relief. Where QOL has been investigated and found to be low postoperatively, this has been attributed to the effects of treatment or cancer progression without formal exploration(46). Chow and colleagues published a large study in 2018 (n=298) investigating the effect of palliative radiotherapy on quality of life measured using the BM22 in patients with bone metastases(48). This demonstrated that younger patients tended to report a poorer baseline quality of life score with more severe treatment-related symptoms of nausea and vomiting compared to elderly patients(48). Patients showed an improvement at 42 days post-treatment in all realms of the EORTC BM22 (painful sites, pain characteristics, functional interference and psychosocial aspects of symptoms) ranging from 3-16%, but required a minimum of 10% change to consider improvement a clinically relevant change(48). The short follow-up duration of this study limits any other conclusions being drawn.
Only two studies investigated QoL after surgery for MBD. These both showed no difference in the Short Form 36 up to 3 months(22) or the QOLLTI-P at up to one year post-surgery(46). We would conclude that there is a requirement for further prospective studies investigating outcomes in terms of quality of life in the MBD population. These studies should follow up patients to a clinically relevant outcome, at least 3-6 months from surgery (12 months after EPR) and should utilise a MBD-specific outcome score, such as the EORTC-QLQ BM22(16).

Psychosocial
None of the studies reviewed explored the effect of surgery for MBD on psychosocial aspects of treatment such as mood, anxiety and depression. Improving pain is associated with reduced depression scores in cancer patients(56) but this is an area which remains under-represented in the literature and requires specific exploration.

To summarise, current studies in the literature exploring patient reported-outcomes in MBD tend to be retrospective or cross-sectional, small in sample size and are inconsistent in terms of the scoring systems used. Many of these are not MBD-specific, although this has improved

in the last ten years in some areas such as function. Current studies neglect to investigate factors associated with good or poor outcome, and neglect quality of life and psychosocial outcome as key aspects of care.

How should PROMs influence clinical decision-making?

Finally, we will address whether PROM scores should be utilised in controlling access to surgery, how they can improve patient care (including measuring the impact of new treatments) and the practicalities of measuring PROMs on a national scale with inclusion in data registries.

Access to surgery

Recently, there has been considerable interest in the use of PROMs to prioritise or control access to surgery(9, 57, 58). Despite the fact that PROMs were initially designed to compare the benefit of different treatments, approaches or implants for a specified condition, they have increasingly been used on a regional basis (particularly in the UK) to guide health boards in prioritising and offering surgery for life-enhancing but not prolonging procedures, such as hip and knee replacements(9, 59). The main argument for use of PROMs in controlling access to surgery is the increased focus this places on life-enhancing outcomes over objective outcomes such as survival and length of hospital stay(9). However, arguments against PROM-related health rationing include concerns about local 'postcode lotteries' and risk of bias against vulnerable patients because of the documented relationship between poor preoperative health, function and mental health status, and poor postoperative outcome(9, 58, 59). In their excellent 2011 study, Judge and colleagues demonstrated that patients with better preoperative functional scores were more satisfied with their surgery, and concluded that preoperative PROM scores cannot reliably predict surgical outcome(9, 60).

Similar difficulties can be expected in MBD, whereby there is insufficient evidence at present to support the benefits of variation in care (such as more or less invasive surgery) and inadequate evidence-based thresholds for benefit from surgery according to patient gender, health status and prognosis(45, 55). For surgery to be deemed successful in MBD, patients must experience pain relief, an improvement in function and satisfaction with the procedure(58, 61). We would recommend that the role for PROMs in MBD is not in determining the severity of symptoms that should be present before surgery is undertaken but in quantifying benefit and comparing any treatments available(58, 62).

Using PROMs to improve patient care

The routine use of PROMs in clinical settings can lead to improvements in patient care, satisfaction and even prolong survival(13, 14, 63). The results from PROM studies have demonstrated benefit from surgery in terms of pain relief, function and quality of life, and have been used to compare and contrast current interventions such as IMN versus EPR(47, 54). In addition, PROMs can be used to test and validate new treatments in MBD, where no survival advantage is expected but efficacy is quantified in terms of functional or quality of life outcome(8, 14).

Inclusion of PROM data on national registries

Finally, PROMS can be used to drive service improvement at the national and international levels via inclusion on data registries(14). Breakwell's 2015 "Should we all go to the PROM?" editorial covering the first two years of the British Spine Registry provides an excellent overview of the benefits of including PROM data on data registries, which include enhancing quality of care, multi-centre comparison of clinically-relevant outcomes and the move towards 'value-based healthcare' (64). Barriers to this include the significant local variation with different PROMs used by different centres, perception of burden of inclusion from participating clinicians and cost (14, 64). The PROMIS score was developed by the National Institute of Health (NIH) to address inconsistencies between different PROM scores(65).

Conclusions and future directions

In conclusion, PROMs should be prioritised in outcome-assessment after surgery for MBD because they reflect the changes in QOL and function that are the key indication for surgery in this group. Oncological procedures such as tumour excision and EPR can be invasive procedures with a significant morbidity(55), so they should only be undertaken when the balance of potential benefit is favourable for individual patients. Assessing patient-reported outcomes is the best way to determine this.

Controversies in uptake of PROM-measurement in orthopaedics include concerns at using PROMs to control access to surgery. We do not recommend this and suggest that PROMs should be used to compare current and novel treatments and not to determine the overall success of a procedure. Alternatives to PROMS such as physician-reported measures and QIs have advantages and disadvantages, and PROM measurement should be used to complement other clinical parameters including objective outcome measurement(14).

The difficulties in measuring PROMs in the MBD population include participant burden and the need to ascertain the outcomes of importance to individual patients. Concerns have been raised that deteriorating function or pain relief over time would provide evidence against surgery in MBD, but there is no evidence to support this.

Future studies incorporating PROMs in outcome-assessment for patients with bone metastases should use measures specific to this population and measure additional outcomes as a 'sense check'(66). To ensure the most relevant outcomes to patients are being assessed, patient and public involvement should be sought during the planning stages of any future studies.

Tables

Table 1 – What outcomes do MBD patients consider important?

Domain	Example
Physical	Pain, fatigue, nausea, energy, loss of appetite(67)
Psychological	Depression, ability to cope, health perception(68)
Function/mobility	Ambulation, continence(21)
Social	Loneliness, sexual function
Financial	Treatment expenses, travelling to appointments
Treatment-related	Treatment burden (e.g. frequency of visits, number of blood draws etc), skeletal-related events (SREs, e.g. fractures, hypercalcaemia)(20)
Adapted from Mougalian *et al.*(13)	

Table 2 – Overview of patient-reported outcome measures (PROMs) in metastatic bone disease (MBD)

	Non-specific	Validated in MBD/orthopaedic oncology
Pain	Brief Pain Inventory Short-Form (BPI-SF)(69) McGill Pain Questionnaire Short-Form (MPQ-SF)(70)	Functional Assessment of Cancer Therapy-Bone Pain (FACT-BP)(26)
Function & mobility	Karnofsky Performance Score (KPS)(2) Eastern Cooperative Oncology Group (ECOG)(71)	Musculoskeletal Tumor Society score (MSTS)(27) Toronto Extremity Salvage score (TESS)(28, 72) Patient-Reported Outcomes Measurement System (PROMIS) Physical Function score(30)
Quality of life	EORTC-QLQ C-30(8, 20) EuroQoL (EQ-5D)(65)	EORTC-QLQ BM22(16) BOMET-QOL(3)
Mood	Hospital anxiety and depression scale (HADS)(32) RSCL(5)	-
Physical/symptoms	Edmonton Symptom Assessment System (ESAS)(33) Rotterdam Symptom Checklist(20)	-

Table 3 – Comparison of objective methods of outcome assessment

	Strengths	Weaknesses
Surgical outcomes e.g. mortality, peri-operative complications	-Easy to measure -Infrastructure already in place to record these	-May not be appropriate in the MBD population
Performance-based outcome measures	-Improved sensitivity versus PROMs e.g. ability to distinguish pain from function(73) -Improved validity to PROMs(9) -Don't show ceiling effects(9)	-Ecological validity – do they measure real-world function?(9) -Hawthorne effect: participant acts differently because they are being observed(73, 74)
Physician-reported outcome measures	-Gold standard for measuring function(9) -Measure objective surgical outcomes e.g. strength, range of movement (ROM)(57) -Minimise ceiling effects(9) -No educational/language barriers	-Expensive and not broadly available(9) -Doesn't necessarily take into account outcomes important to patients -Clinicians overestimate outcome vs patients(30) -Poor inter-observer reliability(73)
Quality indicators of treatment outcome	-Allow comparison between different centres/countries(8, 75) -Can be used to identify complex patients who may benefit from tertiary orthopaedic oncology opinion(76)	-Significant effort required to develop(77) -Need to be validated for specific population(77) -Constantly changing(78) -Can only measure outcomes that are routinely recorded in practice(77)

References

1. Coleman RE. Clinical features of metastatic bone disease and risk of skeletal morbidity. Clin Cancer Res. 2006;12(20 Pt 2):6243s-9s.
2. Matza LS, Fallowfield LJ, Chung KC, Currie BM, Van Brunt K, Patrick DL. Patient-reported outcome instruments used to assess pain and functioning in studies of bisphosphonate treatment for bone metastases. Support Care Cancer. 2012;20(4):657-77.
3. Sureda A, Isla D, Cózar JM, Ruiz M, Domine M, Margelí M, et al. Final development and validation of the BOMET-QoL questionnaire for assessing quality of life in patients with malignant bone disease due to neoplasia. Journal of Medical Economics. 2007;10(1):27-39.
4. British Orthopaedic Oncology Society (BOOS). Metastatic bone disease: A guide to good practice 2015 [Available from: http://www.boos.org.uk/wp-content/uploads/2016/03/BOOS-MBD-2016-BOA.pdf.
5. Cheng EY. Prospective quality of life research in bony metastatic disease. Clin Orthop Relat Res. 2003(415 Suppl):S289-97.
6. Soeharno H, Povegliano L, Choong PF. Multimodal Treatment of Bone Metastasis-A Surgical Perspective. Front Endocrinol (Lausanne). 2018;9:518.
7. Kimura T. Multidisciplinary Approach for Bone Metastasis: A Review. Cancers (Basel). 2018;10(6).
8. Lemke M, Lien K, Zeng L, Popovic M, Zhou M, Digiovanni J, et al. New Considerations in the Design of Clinical Trials for Bone Metastases. World J Oncol. 2012;3(1):1-7.
9. Hossain F.S. KS, Patel S., Rodriguez-Merchan E.C., Haddad F.S.,. The assessment of outcome after total knee
arthroplasty. Bone Joint J. 2015;97-B:3-9.
10. Downie S, Lai FY, Joss J, Adamson D, Jariwala AC. The Metastatic Early Prognostic (MEP) score. Bone Joint J. 2020;102-b(1):72-81.
11. Sorensen MS, Gregersen KG, Grum-Schwensen T, Hovgaard D, Petersen MM. Patient and implant survival following joint replacement because of metastatic bone disease. Acta Orthop. 2013;84(3):301-6.
12. U.S. Department of Health and Human Services Food and Drug Administration. Guidance for industry. Patient-reported outcome measures: Use in medical product development to support labeling claims 2009 [Available from: https://www.fda.gov/media/77832/download.
13. Mougalian SS, Aminawung JA, Presley CJ, Canavan ME, Holland ML, Hu X, et al. Prioritization of Patient-Reported Outcomes by Women With Metastatic Breast Cancer. JCO Clin Cancer Inform. 2019;3:1-3.
14. Eton DT, Beebe TJ, Hagen PT, Halyard MY, Montori VM, Naessens JM, et al. Harmonizing and consolidating the measurement of patient-reported information at health care institutions: a position statement of the Mayo Clinic. Patient Relat Outcome Meas. 2014;5:7-15.
15. Botje D, Ten Asbroek G, Plochg T, Anema H, Kringos DS, Fischer C, et al. Are performance indicators used for hospital quality management: a qualitative interview study amongst health professionals and quality managers in The Netherlands. BMC Health Serv Res. 2016;16(1):574.
16. Chow E, Hird A, Velikova G, Johnson C, Dewolf L, Bezjak A, et al. The European Organisation for Research and Treatment of Cancer Quality of Life Questionnaire for patients with bone metastases: the EORTC QLQ-BM22. Eur J Cancer. 2009;45(7):1146-52.

17. Shirley ED, Sanders JO. Measuring Quality of Care with Patient Satisfaction Scores. J Bone Joint Surg Am. 2016;98(19):e83.
18. Depuy V, Anstrom K, Castel L, Schulman K, Saad F, Barghout V, et al. Effects of skeletal morbidities on longitudinal patient-reported outcomes and survival in patients with metastatic prostate cancer. European Urology Supplements. 2006;5(2):58.
19. Weinfurt KP, Li Y, Castel LD, Saad F, Timbie JW, Glendenning GA, et al. The significance of skeletal-related events for the health-related quality of life of patients with metastatic prostate cancer. Ann Oncol. 2005;16(4):579-84.
20. Tharmalingam S, Chow E, Harris K, Hird A, Sinclair E. Quality of life measurement in bone metastases: A literature review. J Pain Res. 2008;1:49-58.
21. O'Toole DM, Golden AM. Evaluating Cancer Patients for Rehabilitation Potential. West J Med. 1991;155(4):384-7.
22. Talbot M, Turcotte RE, Isler M, Normandin D, Iannuzzi D, Downer P. Function and health status in surgically treated bone metastases. Clin Orthop Relat Res. 2005;438:215-20.
23. Gater A, Abetz-Webb L, Battersby C, Parasuraman B, McIntosh S, Nathan F, et al. Pain in castration-resistant prostate cancer with bone metastases: a qualitative study. Health Qual Life Outcomes. 2011;9:88.
24. Cleeland CS. The measurement of pain from metastatic bone disease: capturing the patient's experience. Clin Cancer Res. 2006;12(20 Pt 2):6236s-42s.
25. Popovic M, Nguyen J, Chen E, Di Giovanni J, Zeng L, Chow E. Comparison of the EORTC QLQ-BM22 and the FACT-BP for assessment of quality of life in cancer patients with bone metastases. Expert Rev Pharmacoecon Outcomes Res. 2012;12(2):213-9.
26. Broom R, Du H, Clemons M, Eton D, Dranitsaris G, Simmons C, et al. Switching breast cancer patients with progressive bone metastases to third-generation bisphosphonates: measuring impact using the Functional Assessment of Cancer Therapy-Bone Pain. J Pain Symptom Manage. 2009;38(2):244-57.
27. Enneking WF, Dunham W, Gebhardt MC, Malawar M, Pritchard DJ. A system for the functional evaluation of reconstructive procedures after surgical treatment of tumors of the musculoskeletal system. Clin Orthop Relat Res. 1993(286):241-6.
28. Davis AM, Wright JG, Williams JI, Bombardier C, Griffin A, Bell RS. Development of a measure of physical function for patients with bone and soft tissue sarcoma. Qual Life Res. 1996;5(5):508-16.
29. Janssen SJ, van Rein EA, Paulino Pereira NR, Raskin KA, Ferrone ML, Hornicek FJ, et al. The Discrepancy between Patient and Clinician Reported Function in Extremity Bone Metastases. Sarcoma. 2016;2016:1014248.
30. Janssen SJ, Paulino Pereira NR, Raskin KA, Ferrone ML, Hornicek FJ, van Dijk CN, et al. A comparison of questionnaires for assessing physical function in patients with lower extremity bone metastases. J Surg Oncol. 2016;114(6):691-6.
31. Blank AT, Lerman DM, Shaw S, Dadrass F, Zhang Y, Liu W, et al. PROMIS (R) scores in operative metastatic bone disease patients: A multicenter, prospective study. J Surg Oncol. 2018;118(3):532-5.
32. Zigmond AS, Snaith RP. The hospital anxiety and depression scale. Acta Psychiatr Scand. 1983;67(6):361-70.
33. Bruera E, Kuehn N, Miller MJ, Selmser P, Macmillan K. The Edmonton Symptom Assessment System (ESAS): a simple method for the assessment of palliative care patients. J Palliat Care. 1991;7(2):6-9.

34. Scott CEH, Howie CR, MacDonald D, Biant LC. Predicting dissatisfaction following total knee
replacement. Journal of Bone & Joint Surgery (Br). 2010;92-B(9):1253-8.
35. Jacobs CA, Christensen CP, Karthikeyan T. Patient and intraoperative factors influencing satisfaction two to five years after primary total knee arthroplasty. J Arthroplasty. 2014;29(8):1576-9.
36. Gandhi R, Davey JR, Mahomed NN. Predicting Patient Dissatisfaction Following Joint Replacement Surgery. The Journal of Rheumatology. 2008;35(12):2415-8.
37. Nam D, Nunley RM, Barrack RL. Patient dissatisfaction following total knee replacement. The Bone & Joint Journal. 2014;96-B(11):96-100.
38. Conway JL, Yurkowski E, Glazier J, Gentles Q, Walter A, Bowering G, et al. Comparison of patient-reported outcomes with single versus multiple fraction palliative radiotherapy for bone metastasis in a population-based cohort. Radiother Oncol. 2016;119(2):202-7.
39. Jensen RE, Potosky AL, Reeve BB, Hahn E, Cella D, Fries J, et al. Validation of the PROMIS physical function measures in a diverse US population-based cohort of cancer patients. Qual Life Res. 2015;24(10):2333-44.
40. Ratasvuori M, Wedin R, Keller J, Nottrott M, Zaikova O, Bergh P, et al. Insight opinion to surgically treated metastatic bone disease: Scandinavian Sarcoma Group Skeletal Metastasis Registry report of 1195 operated skeletal metastasis. Surg Oncol. 2013;22(2):132-8.
41. Lim CR, Harris K, Dawson J, Beard DJ, Fitzpatrick R, Price AJ. Floor and ceiling effects in the OHS: an analysis of the NHS PROMs data set. BMJ Open. 2015;5(7):e007765.
42. Mueller K. Commentary: Ernest Codman and the Impact of Quality Improvement in Neurosurgery: A Century Since the Idea of the “End Result”. Neurosurgery. 2018;84(2):E116-E9.
43. Furtado S, Grimer RJ, Cool P, Murray SA, Briggs T, Fulton J, et al. Physical functioning, pain and quality of life after amputation for musculoskeletal tumours: a national survey. Bone Joint J. 2015;97-b(9):1284-90.
44. Mercadante S. Malignant bone pain: pathophysiology and treatment. Pain. 1997;69(1-2):1-18.
45. Janssen SJ, Pereira NRP, Thio Q, Raskin KA, Bramer JAM, Lozano-Calderon SA, et al. Physical function and pain intensity in patients with metastatic bone disease. J Surg Oncol. 2019;120(3):376-81.
46. Nooh A, Goulding K, Isler MH, Mottard S, Arteau A, Dion N, et al. Early Improvement in Pain and Functional Outcome but Not Quality of Life After Surgery for Metastatic Long Bone Disease. Clin Orthop Relat Res. 2018;476(3):535-45.
47. Piccioli A, Maccauro G, Rossi B, Scaramuzzo L, Frenos F, Capanna R. Surgical treatment of pathologic fractures of humerus. Injury. 2010;41(11):1112-6.
48. Chow S, Ding K, Wan BA, Brundage M, Meyer RM, Nabid A, et al. Patient Reported Outcomes After Radiation Therapy for Bone Metastases as a Function of Age: A Secondary Analysis of the NCIC CTG SC-Twenty-Three Randomized Trial. Am J Hosp Palliat Care. 2018;35(4):718-23.
49. Hattori H, Mibe J, Yamamoto K. Modular megaprosthesis in metastatic bone disease of the femur. Orthopedics. 2011;34(12):e871-6.
50. Potter BK, Chow VE, Adams SC, Letson GD, Temple HT. Endoprosthetic proximal femur replacement: metastatic versus primary tumors. Surg Oncol. 2009;18(4):343-9.

51. Selek H, Basarir K, Yildiz Y, Saglik Y. Cemented endoprosthetic replacement for metastatic bone disease in the proximal femur. J Arthroplasty. 2008;23(1):112-7.
52. Peterson JR, Decilveo AP, O'Connor IT, Golub I, Wittig JC. What Are the Functional Results and Complications With Long Stem Hemiarthroplasty in Patients With Metastases to the Proximal Femur? Clin Orthop Relat Res. 2017;475(3):745-56.
53. Park DH, Jaiswal PK, Al-Hakim W, Aston WJ, Pollock RC, Skinner JA, et al. The use of massive endoprostheses for the treatment of bone metastases. Sarcoma. 2007;2007:62151.
54. Bickels J, Kollender Y, Wittig JC, Meller I, Malawer MM. Function after resection of humeral metastases: analysis of 59 consecutive patients. Clin Orthop Relat Res. 2005(437):201-8.
55. Harvey N, Ahlmann ER, Allison DC, Wang L, Menendez LR. Endoprostheses last longer than intramedullary devices in proximal femur metastases. Clin Orthop Relat Res. 2012;470(3):684-91.
56. Jack L, Scott A, Colvin L, Laird B, Fallon M. Pain and depression in cancer patients: a longitudinal study. BMJ Supportive & Palliative Care. 2011;1(Suppl 1):A11-A.
57. Graham B, Green A, James M, Katz J, Swiontkowski M. Measuring patient satisfaction in orthopaedic surgery. J Bone Joint Surg Am. 2015;97(1):80-4.
58. A. J, K. AN, A. P, S. G-J, D. B, J. CA, et al. Assessing patients for joint replacement; Can pre-operative Oxford hip and knee scores be used to predict patient satisfaction following joint replacement surgery and to guide patient selection? The Journal of Bone and Joint Surgery British volume. 2011;93-B(12):1660-4.
59. Dakin H, Gray A, Fitzpatrick R, Maclennan G, Murray D, Group KATT. Rationing of total knee replacement: a cost-effectiveness analysis on a large trial data set. BMJ Open. 2012;2(1):e000332.
60. Judge A, Arden NK, Price A, Glyn-Jones S, Beard D, Carr AJ, et al. Assessing patients for joint replacement: can pre-operative Oxford hip and knee scores be used to predict patient satisfaction following joint replacement surgery and to guide patient selection? J Bone Joint Surg Br. 2011;93(12):1660-4.
61. Dorr LD, Chao L. The Emotional State of the Patient after Total Hip and Knee Arthroplasty. Clin Orthop Rel Res. 2007;PAP.
62. Gossec L, Paternotte S, Maillefert JF, Combescure C, Conaghan PG, Davis AM, et al. The role of pain and functional impairment in the decision to recommend total joint replacement in hip and knee osteoarthritis: an international cross-sectional study of 1909 patients. Report of the OARSI-OMERACT Task Force on total joint replacement. Osteoarthritis Cartilage. 2011;19(2):147-54.
63. Hahn EA, Cella D, Chassany O, Fairclough DL, Wong GY, Hays RD. Precision of health-related quality-of-life data compared with other clinical measures. Mayo Clin Proc. 2007;82(10):1244-54.
64. Breakwell LM, Cole AA, Birch N, Heywood C. Should we all go to the PROM? The first two years of the British Spine Registry. Bone Joint J. 2015;97-b(7):871-4.
65. Rothrock NE, Kaiser KA, Cella D. Developing a valid patient-reported outcome measure. Clin Pharmacol Ther. 2011;90(5):737-42.
66. Calvert M, Blazeby J, Altman DG, Revicki DA, Moher D, Brundage MD, et al. Reporting of Patient-Reported Outcomes in Randomized Trials: The CONSORT PRO Extension. JAMA. 2013;309(8):814-22.

67. Eton DT SD, Beaumont J, Victorson D, Cella D. Constructing a Conceptual Framework of Patient-Reported Outcomes for Metastatic Hormone-Refractory Prostate Cancer. Value in Health. 2010;13(5):613-23.
68. Adrover E, Allepuz J, Sureda A, Domine M, Barnadas A, Constela M, et al. Development of a questionnaire to measure health-related quality of life (HRQoL) in patients with bone metastases (BOMET-QoL). Journal of Outcomes Research. 2005;9(15):15-27.
69. Cleeland CS. The Brief Pain Inventory User Guide. 2009.
70. Melzack R. The short-form McGill Pain Questionnaire. Pain. 1987;30(2):191-7.
71. Oken MM, Creech RH, Tormey DC, Horton J, Davis TE, McFadden ET, et al. Toxicity and response criteria of the Eastern Cooperative Oncology Group. Am J Clin Oncol. 1982;5(6):649-55.
72. Ploetze KL, Dalton JF, Calfee RP, McDonald DJ, O'Keefe RJ, Cipriano CA. Patient-Reported Outcomes Measurement Information System physical function correlates with Toronto Extremity Salvage Score in an orthopaedic oncology population. Journal of Orthopaedic Translation. 2019.
73. S. K, F. H, S. P, S. HF. Measuring function after hip and knee surgery. The Bone & Joint Journal. 2014;96-B(11):1431-5.
74. Lied TR, Kazandjian VA. A Hawthorne strategy: implications for performance measurement and improvement. Clin Perform Qual Health Care. 1998;6(4):201-4.
75. <Baillie - NICE Quality Standards and Indicators.pdf>.
76. Oliver TB, Bhat R, Kellett CF, Adamson DJ. Diagnosis and management of bone metastases. J R Coll Physicians Edinb. 2011;41(4):330-8.
77. Kotter T, Schaefer FA, Scherer M, Blozik E. Involving patients in quality indicator development - a systematic review. Patient Prefer Adherence. 2013;7:259-68.
78. Bennett B, Coventry E, Greenway N, Minchin M. The NICE process for developing quality standards and indicators. Z Evid Fortbild Qual Gesundhwes. 2014;108(8-9):481-6.

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